



Trans Forum

News From Argonne's Transportation Technology R&D Center



Page 2

■ VIEWPOINT

DOE's GATE Program

A partnership among government, academia, and industry will provide qualified engineers to build tomorrow's alternative fuel vehicles

The U.S. Department of Energy's Graduate Automotive Technology Education (GATE) program blends graduate-level education with technology development and transfer by training students of automotive engineering in critical multidisciplinary technologies, fostering cooperative research in those technologies, and transferring those technologies directly to industry. *Page 2*



Page 5

■ RESEARCH REVIEW

Underhood Thermal Modeling Undergoes Big Improvements

Argonne and its partners simulate intense heat in confined spaces

Automotive engineers can now simulate the complex operating environment under the hood of your car or truck thanks to new high-performance computer models under development by Argonne and industry partners. The modeling software simulates complex fluid flows and heat transfer in underhood systems, including hybrid-electric vehicles and conventional passenger cars, to help vehicle manufacturers assess the interdependence of the components, study heat load conditions, and identify critical components. *Page 4*

Ceramic Materials Take Charge

Revolutionary capacitors for power electronics pack a mega-charge in a mini-space

Argonne is working to improve high-power capacitors by using thin-film ceramics. Improving the capacitors, which take up about 70% of the volume of a typical power electronics module, would be a major step toward making the module lighter, more efficient, and cheaper. *Page 5*



Page 6

Solid Free-Form Fabrication: Breaking the Mold

Argonne researchers perfect a technology to speed design and fabrication of vehicle components

Investing in a tooling die is not taken lightly in the transportation industry or in any other manufacturing realm. Argonne researchers are refining solid free-form fabrication (also known as "rapid prototyping") technology to help companies inexpensively reduce the time required to go from design to finished part. Specifications can be adjusted and retested before the design is cast into a costly die. *Page 6*

■ LOOKING DOWN THE ROAD *Page 7*

■ FASTRAX *Page 7*

■ PARTNERING WITH ARGONNE *Page 8*



DOE's GATE Program

A partnership among government, academia, and industry will provide qualified engineers to build tomorrow's alternative fuel vehicles

If you were to read the course descriptions for today's graduate engineering curricula, you might be surprised: instead of traditional engineering courses and facilities, you might find such courses and facilities as "Hybrid-Electric Vehicles and Controls" and "Automotive Fuel Cell Systems Laboratory." These and other similar resources at some of the top engineering schools in the United States are hallmarks of GATE — the U.S. Department of Energy's (DOE's) Graduate Automotive Technology Education program.

Initiated in 1998, the two-phase GATE program is unique because it blends graduate-level education with technology development and transfer by training students of automotive engineering in critical multidisciplinary technologies, fostering cooperative research in those technologies, and transferring the technologies directly to industry. The program focuses on five key technology areas: hybrid-electric vehicles, fuel cells, direct-injection engines, energy storage, and lightweight materials.

In its first phase (fall of 1998), GATE provided a \$100,000 grant to each of 10 leading engineering universities to develop programs of focused technology instruction and research in the five key technology areas. In its second phase, GATE provided each participating school an additional \$100,000 for fellowships to graduate students enrolled in GATE programs. The 12-month fellowships were awarded for study and research leading to master and doctoral degrees in engineering sciences, with a concentration in one of the five key technology areas.

DOE's Office of Advanced Automotive Technologies (OAAT) and industry partners are GATE's driving forces. Argonne National Laboratory also has a significant technical and ad-

ministrative role in the program. The Center for Transportation Research at Argonne assists DOE in managing the GATE program — providing technical monitoring and evaluation, developing communication and promotional materials, overseeing research activities, and testing the technologies that the students develop. Argonne also provided technical support and guidance for the GATE solicitation and selection process.

In a dynamic field like automotive engineering, OAAT and industry realized that only a knowledgeable, experienced workforce, equipped with cutting-edge and cross-disciplinary skills, can move the newest, most sophisticated technologies to production — especially in the near term. Few colleges and universities have the resources to provide students with the comprehensive training they need to be that workforce. That's where GATE comes in.

"Most OAAT programs are focused exclusively on technology development. However, the twin goals of developing innovative technologies and transferring them to industry led OAAT to realize the growing need for people trained in non-traditional, emerging technologies," said JoAnn Milliken, GATE Program Manager.

Technology transfer is built right into the GATE program as a fundamental component of the educational process. "Through the GATE program, DOE hopes to attract bright, talented students who can accelerate the progress and development of vehicles that reduce emissions and significantly improve energy efficiency," said Secretary of Energy Bill Richardson. "The GATE program also will prepare a new generation of engineers and scientists with the technical knowledge and skills necessary to lead our country's automotive industry in the future," Richardson adds.

Working with industrial sponsors, GATE scholars develop research projects in the key DOE technology areas, tailoring their thesis projects to the specific interests and needs of industry and thereby accelerating the development of technologies relevant to DOE's mission. Technology transfer



Engineering students at Pennsylvania State University test their hybrid-electric vehicle, the "Electric Lion," on a chassis dynamometer.



continues upon graduation, when the new engineers — who are experts in much-needed specialties — join the automotive industry and begin applying their expertise on the job.

For example, GATE Fellowship students at the University of California, Davis, are interacting with a “real-world” industrial base made up of 16 partners (such as British Petroleum, Exxon, General Motors, and Honda). The Ohio State University (OSU) GATE program is also supported by a number of industrial partners. As one of its focus areas, OSU’s recently formed Center for Automotive Research Industrial Consortium is funding a project to develop control strategies for hybrid-electric drivetrains. The Consortium consists of a pre-competitive partnership involving Bosch, Delphi Automotive Systems, Ford, General Motors, Honda, and Visteon.

The 10 universities selected to develop a GATE Center and their respective technology areas are:

- Fuel Cells: University of California, Davis; Virginia Tech
- Hybrid Drivetrains and Control Systems: University of Maryland; University of Tennessee; Ohio State University; West Virginia University; University of California, Davis
- Lightweight Materials: University of Michigan–Dearborn
- Direct-Injection Engines: Michigan Tech
- Energy Storage: Pennsylvania State University

To be selected, each school had to meet some very stringent requirements. Each proposed a curriculum and process for guiding and administering the academic and research aspects of the GATE program. Each school also had to have significant experience with one or more of the key technologies and have access to laboratory facilities and equipment to support their proposed programs.

GATE is still a pilot program. In the future, DOE may expand the topics, the number of universities participating, and perhaps the number of fellowships offered under the program.

Contact

JoAnn Milliken
DOE-Headquarters
Phone: 202/586-2480
Fax: 202/586-9811
e-mail: JoAnn.Milliken@hq.doe.gov

Faculty and students involved in GATE are enthusiastic about the program, particularly about what it promises to deliver. Said Professor Dan Sperling, Institute of Transportation Studies, University of California, Davis, “I believe the GATE program is critically important to America’s leadership in advanced technology vehicles. But technology revolutions don’t appear out of thin air. Where will the next generation of engineers and scientists come from? Almost none are being trained at our universities. The GATE program is a first step in bringing attention and resources to this problem. DOE should be complimented on its leadership and vision in fast-tracking this program.”

David Smith, Ph.D. student and GATE Fellow from the University of Tennessee, agrees: “Continuing concerns



*University of Tennessee
GATE Fellow David Smith*

over automotive exhaust emissions and the demand for increased fuel economy warrant the creation of these programs,” he said. “The GATE program offers industry the opportunity to find solutions to these problems through the creation of a skilled technical workforce specializing in hybrid-electric vehicle design.”

A doctoral student with interests in the automotive field, Smith feels strongly that the program provides “a positive and concentrated atmosphere that allows students to develop the necessary tools to *apply* hybrid-electric vehicle technology. While the program builds a firm foundation in classroom theory, it also provides students with a ‘proving ground’ to substantiate and validate what they’ve learned.”

In addition, Smith believes, GATE addresses the importance of developing cross-discipline engineers through the intertwining of electrical and mechanical engineering principles. “A hybrid-electric vehicle, by its very nature,” observes Smith, “brings together these two basic disciplines — the auto industry needs skilled engineers who know how these components become one entity. The GATE program fulfills this need.”



Underhood Thermal Modeling Undergoes Big Improvements

Argonne and its partners simulate intense heat in confined spaces

A stream of air roars through narrow openings into near-total darkness before being captured, compressed, and ignited. This complex process, involving hundreds of variables, repeats thousands of times each minute as exhaust fans and coolant systems struggle to combat rising temperatures. Could you accurately simulate such an environment?

Now automotive engineers can, thanks to new high-performance computer models under development by Argonne and industry partners in collaboration with General Motors, Ford, and DaimlerChrysler. The modeling software simulates complex fluid flows and heat transfer in underhood systems for automobiles, including hybrid-electric vehicles and conventional passenger cars.

More power electronics and increasingly complex vehicle operating conditions require early diagnosis and correction of potential heat load problems to help reduce design time and cost. This is why scientists from Argonne have teamed with research partners like Analysis and Design Application Company (adapco) of Melville, New York, to improve underhood heat load modeling.

Using computational fluid dynamics (CFD) software, the researchers plan to eventually extend the software to model three-

dimensional fluid flow and heat transfer for entire vehicles, providing a “virtual test facility” that could help vehicle manufacturers assess the interdependence of underhood components, study heat-load conditions, and identify critical components.

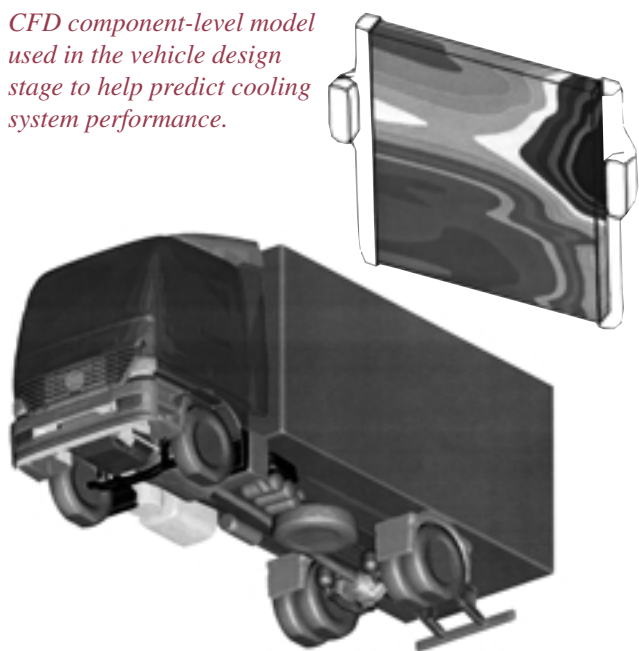
According to David Weber, Associate Director of Argonne’s Reactor Engineering Division, who leads Argonne’s modeling project with adapco, “The automotive industry is moving away from using only experimental testing for validating vehicle designs and is starting to use more analytical testing, which helps predict vehicle performance *before* it’s built. Argonne’s ability to provide numerical models that more accurately simulate car and truck underhood system performance will soon help vehicle manufacturers reduce the number of prototypes they need to build. The potential savings for these manufacturers is enormous.”

The availability of faster and cheaper computers and the increasing use of sophisticated computer-aided design (CAD) by carmakers has helped numerical modeling gain wider acceptance in the automotive industry. Modeling speed and accuracy have increased dramatically. “Our first underhood thermal model was developed for Mercedes in the mid-1990s, and the process took more than a year. Now we can build that same type of model in a matter of weeks,” says Steve MacDonald, adapco president.

MacDonald explains that adapco has benefited from Argonne’s experience in developing models that represent entire vehicle systems. “Our strength was in specific component-level modeling, and we were able to integrate this knowledge with Argonne’s expertise in systems-level models.”

As the researchers further refine the underhood models, they plan to extend their work to include underhood thermal management for trucks and other heavy vehicles. John Hull of Argonne’s Energy Technology Division and coordinator of the DOE/OHVT Thermal Management Program explains that “managing underhood airflow is especially critical for optimizing the design of trucks to improve fuel economy and reduce aerodynamic drag.”

CFD component-level model used in the vehicle design stage to help predict cooling system performance.



Large model (6 million cells) shows CFD software capabilities in helping assess vehicle aerodynamic performance and thermal management system effectiveness.

Contact

David Weber
phone: 603/252-8175
fax: 630/252-4780
e-mail: dpweber@anl.gov



Ceramic Materials Take Charge

Revolutionary capacitors for power electronics pack a mega-charge in a mini-space

An electric vehicle depends on its power electronics package the way a theater company depends on its stage manager. Both are responsible for getting things to the right place at the right time in the right condition. A good stage manager frees the actors to give their best performances. Likewise, better power electronics will help low-emission electric and hybrid-electric vehicles (EVs and HEVs) put on a good show for Planet Earth.

In EVs and HEVs, the power electronics module directs and modifies electricity within the drivetrain. High-power capacitors are critical, and ubiquitous, components of this module. For example, these capacitors are particularly important in the inverter, which converts direct current from the battery to alternating current for the electric drive system.

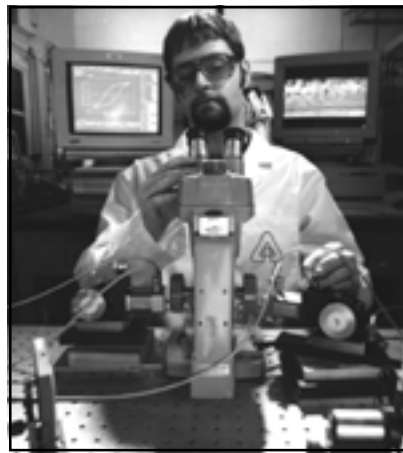
For these vehicles to be competitive in cost and performance, the power electronics module must be lighter, more efficient, and cheaper. Improving the capacitors, which take up about 70% of the volume of a typical module, would be a major step toward solving all three problems.

Argonne is working on this three-for-one improvement by exploring a different approach for high-power capacitors: thin-film ceramics. "We're going at this problem from two angles," says David Kaufman, a member of Argonne's Energy Technology Division and one of the principal investigators on the project. "One angle is using advanced ceramic materials that have a high dielectric constant to get better performance. The second is making these materials using thin-film techniques from the semiconductor industry to reduce both the size and the cost. This combination of technologies is pretty unusual." The size factor could be significant: capacitors that are now as big as soda cans might someday fit in a thimble.

"The really exciting thing about using thin films is that it should also be possible to integrate some of the capacitors right into the semiconductor switching circuitry, which would eliminate a lot of manufacturing steps," says Kaufman.

A capacitor consists of an insulator (a "dielectric" material) separating two charge-collecting electrodes. The dielectric constant quantifies how much charge the capacitor can store. The capacitor works something like a double-sided piece of Velcro: positive charge in the electrical circuit "sticks" to one side and negative charge to the other. In a way, the dielectric constant corresponds to the number of Velcro "hooks."

The material Kaufman and his colleagues are studying is $(\text{Ba}_{1-x}\text{Sr}_x)\text{TiO}_3$, or barium strontium titanate (BST), which is a "ferroelectric" ceramic. "Ferroelectric materials behave something like familiar magnetic materials, such as iron," said



Argonne researcher James Giumarra uses an electrical probe station to examine the dielectric properties of the thin-film capacitors.

Stephen Streiffer of Argonne's Materials Science Division. "That is, they have a strong natural tendency to become polarized in an electric field," just as a nail becomes magnetized when held near a magnet. "That's what we mean by a high dielectric constant. When we apply a given electric field, the BST reacts 10 to 100 times more strongly than other capacitor materials, such as polymers," Streiffer explained. Thus, for the same field (i.e., voltage), a small piece of BST can store the same amount of charge as a much larger piece of conventional capacitor material. It's like using a smaller piece of Velcro with a lot more hooks.

The Argonne capacitors are made by using an industrial technique called metal-organic chemical vapor deposition (MOCVD). The BST films are less than half a micrometer thick, or about 1/30th the thickness of typical aluminum foil. The team is studying the fundamental nature of the material and the process to find an optimal combination.

The principal sponsor of this research is the U.S. Department of Energy's Office of Advanced Automotive Technologies. Argonne has also collaborated with industry partners during this project. A portion of the work on BST thin films is supported by the Defense Advanced Research Projects Agency (DARPA) as part of an effort to develop Frequency Agile Materials for Electronics (FAME).

Contact

U. Balachandran
Phone: 630/252-4250
Fax: 630/252-3604
E-mail: balu@anl.gov



Solid Free-Form Fabrication: Breaking the Mold

Argonne researchers perfect a technology to speed design and fabrication of vehicle components

Investing in a tooling die is not taken lightly in the transportation industry or in any other manufacturing realm. With the cost of a die typically running from a half to several million dollars, manufacturers want to be sure a design isn't flawed before they quite literally cast it in stone.

Argonne researchers are refining solid free-form fabrication (SFF — also known as “rapid prototyping”) technology to help companies inexpensively reduce the time required to go from design to finished part. Specifications can be adjusted and retested before the design is cast into a costly die.

In SFF a finished part “materializes” directly from a computer-generated design file. Specially formulated liquid or solid polymers, ceramics, or metals are deposited, photopolymerized, or laser-sintered to shape the part as directed by a succession of thin cross-sections of the design file. (If no design file exists for a component, Argonne can create one using three-dimensional tomographic imaging.)

The Argonne SFF method uses a sweeping material-feed head that deposits material on an inert surface. In one version, the material is extruded as a high-viscosity material (like toothpaste); in another, tiny droplets are launched by means of

technology similar to that of a dot-matrix printer. In a joint research project with Ford Advanced Manufacturing to study the potential for extending a die's life, Argonne used SFF to fabricate a ceramic insert in a high-wear section of a tool. Argonne has also collaborated on SFF projects with Advanced Ceramics Research, Ballistic Particle Machines, Lone Peak Engineering, Midwest Orthopedics, Scientific Measurement Systems, Spectra Group, Stratasys Ltd., and Zimmer Corporation.

In addition to creating prototype parts in hours instead of months, SFF may sometimes eliminate the need for dies by fabricating many parts at once. “Theoretically, a thousand material-feed heads could be attached to one giant SFF system,” said Bill Ellingson, leader of Argonne's SFF research.

The implications for distributed manufacturing and remote machining are enormous, Ellingson noted. Designs can be created in one country and beamed by satellite to other parts of the world where the manufacturing takes place.

Significant savings in time and money are important benefits of SFF. But for some applications, such as the emerging field of automotive sensors, SFF may be the best fabrication method because it can yield a uniquely complex finished part. A part created by the deposition of tiny droplets can have a vastly more delicate and convoluted infrastructure than can a molded part. Provided that appropriate materials can be formulated, droplet-deposition SFF may be the best tool available for the manufacture of extremely intricate electronic circuits, especially for applications in which complex sensors would improve automotive controls.

“Argonne's developments in ceramic SFF, and our related ongoing research in sensors, makes us ideally suited for this type of advanced sensor development,” Ellingson said. Other U.S. research centers pursuing SFF-formed ceramic materials include Rutgers University, The University of Michigan, and AlliedSignal Corporation's research center.



In die-life extension research for Ford Advanced Manufacturing, Argonne used a Ford-generated CAD file as input for solid free-form fabrication to create the ceramic die insert shown here. The insert is for an injection molding die used to make automotive panels — it forms one of the instrument cluster holes.

For more information
contact Bill Ellingson
phone: 630/252-5068
fax: 630/252-4798
e-mail: ellingson@anl.gov



In the first months of the new century, those of us in the Transportation Technology Research and Development Center here at Argonne are eagerly anticipating the advances in technology that are expected over the next decade. The next 10 years promise a century's worth of progress — in computers, medicine, and particularly transportation.

DaimlerChrysler, at the unveiling of its PNGV Concept Car — the ESX3 — observed that during the last century, the automobile shaped society, but in the 21st century, the auto will be shaped by society. The race is on to develop affordable vehicles that can deliver ultralow emissions and, where fuel prices are high, very energy efficient vehicles. Ford Chairman Bill Ford recently provided his vision that “the automotive business is about to be revolutionized by fuel cells and hybrid-electric vehicles.”

While much hard work remains to make the concept cars of DaimlerChrysler, Ford, and General Motors an affordable reality for consumers, numerous activities at the U.S. Department of Energy and its national laboratories are helping to speed this process. A few are highlighted in this issue of TransForum.

One way to help transform Bill Ford's vision into a reality is through DOE's Graduate Automotive Technology Education (GATE) program — a partnership among government, academia, and industry (see story on page 2). The program, which provides grants to 10 top engineering schools and one-year fellowships to graduate engineering students, is helping to ensure that qualified engineers will be on hand to design and build the complex vehicles of the future.

Argonne's contributions to helping the transportation industry fulfill the promise of the next decade include our work with several industry partners to develop three-dimensional models that would provide a “virtual test facility” to help vehicle manufacturers assess the interdependence of underhood components, study heat load conditions, and identify critical components (page 4).

Researchers in the Lab's Energy Technology and Materials Science Divisions are working together to improve the high-power capacitors used in the power electronics modules for electric and hybrid-electric vehicles (see story on page 5). Improvements in these capacitors will make the modules lighter, more efficient, and cheaper.

Research on new vehicle component fabrication techniques here at Argonne will help the automotive industry reduce the time required to go from design to finished part (page 6). Through the use of Argonne's solid free-form fabrication (also known as “rapid prototyping”) technology, specifications can be adjusted and parts retested before a design is cast into a costly die.

As you read about our research in this issue, please feel free to

call the scientists and engineers whose names are listed at the end of each article. They will be happy to provide more details about their technologies and explain how we can collaborate in the transportation revolution that the next 10 years will bring.



Larry R. Johnson
Director



Please join us in congratulating Robert Larsen on his promotion to Director of the Center for Transportation Research in Argonne's Energy Systems Division. Bob, a longtime member of the division, has most recently served as the Leader of the Vehicle Systems and Fuels Section. He is Argonne's lead on DOE's student vehicle competitions and the GATE and CARAT programs and also directs the research efforts in the Laboratory's Engine Research and Advanced Powertrain Facilities.

Argonne's lithium/polymer battery technology garnered public attention in January 2000 as GM unveiled its Precept concept car at the North American International Auto Show in Detroit. The Precept, a hybrid-electric vehicle that can carry five passengers, has a fuel economy of 80 miles per gallon of gas. The Precept is driven by a small diesel engine and an

electric motor powered by a lithium/polymer battery. The battery in the Precept, built for GM by 3M and Hydro-Québec, is based on technology developed under a Cooperative Research and Development Agreement (CRADA) between Argonne, 3M, HydroQuebec, and the United States Advanced Battery Consortium (USABC). Argonne's project team, led by **Dennis Dees**, provided electrode materials development, electrochemical testing and characterization, modeling, and battery design under the CRADA agreement.

TransForum has received an “Excellence Award” in the 27th Annual Chicago Technical Publications, Art, and On-Line Communications Competition. This award indicates that “the judges found the newsletter consistently met high standards in all areas and demonstrated an exceptional understanding of technical communications principles.”



Argonne is seeking industrial partners to develop advanced transportation technologies. The following types of working arrangements can be made:

- In a *reimbursable R&D agreement*, Argonne's industrial partner pays the full cost of the research performed. The company generally takes title to any inventions, and proprietary information and research results are kept confidential.
- In a *cost-shared R&D agreement*, Argonne and its industrial partner share the costs of research. The company may obtain rights to intellectual property developed by Argonne. Proprietary information is kept confidential, and research results may be protected from disclosure for up to five years.

■ *Licenses* for Argonne inventions and software may be granted to companies that wish to develop them into marketable products or processes. Licenses may also be part of other agreements.

■ *Personnel exchanges* and *technical assistance* projects can be arranged with Argonne for short-term or rapid-turnaround work.

For more information about working with Argonne, contact:

Industrial Technology Development Center
Argonne National Laboratory, Bldg. 201
9700 South Cass Avenue, Argonne, IL 60439
phone: 800/627-2596, fax: 630/252-5230
e-mail: partners@anl.gov
Web: <http://www.itd.anl.gov/>

TransForum ■ Volume 2, No. 4, Winter 1999/2000

Contributors: Jane Andrew, Paul Boisvert, Mary Fitzpatrick, and Cathy Kaicher.

TransForum is published by the Transportation Technology R&D Center, Argonne National Laboratory. Publishing support services are provided by Argonne's Information and Publishing Division. Art direction/design by Mary Ann Forys.

Information in *TransForum* may be reproduced for publication with acknowledgment to *TransForum*, Argonne National Laboratory. Address correspondence, subscription requests, and address changes to:

Mary Fitzpatrick
TransForum
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 362
Argonne, IL 60439-4815
phone: 630/252-5037
fax: 630/252-7406
e-mail: mfitzpatrick@anl.gov



Printed on recycled paper.

Argonne National Laboratory is operated by The University of Chicago for the U.S. Department of Energy under contract No. W-31-109-Eng-38. The U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes. This publication was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe on privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.



TransForum is available on-line at <http://www.transportation.anl.gov/ttrdc/publications/transforum/transforum.html>



Non-Profit Organization
U.S. Postage Paid
Lemont, IL
Permit No. 87